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Montana. State Water Projects Bureau
Willow Creek Dam

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WILLOW CREEK DAM

MANUAL FOR OPERATION AND MAINTENANCE

STATE WATER PROJECTS BUREAU
WATER RESOURCES DIVISION
DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
1520 EAST SIXTH AVENUE
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MARCH 1995

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State Water Projects Bureau
Water Resources Division
Department of Natural Resources and Conservation
1520 East Sixth Avenue
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March 1995

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OVERVIEW

Willow Creek Dam is located in Madison County, 3 stream miles southwest of the line separating Madison and Gallatin Counties (Figure 1). The project is approximately 10 miles upstream of the town of Willow Creek, 4 miles east of the town of Harrison, and 17 miles upstream of the city of Three Forks (Figure 2). The reservoir is fed by Willow Creek from the west and Norwegian Creek from the south.

The earthfill dam was constructed in 1938. Willow Creek Dam is 105 feet high and 453 feet long. The dam's outlet works consist of an 8-foot diameter dry well containing a 54-inch diameter emergency gate and a 54-inch diameter butterfly operating valve. The operating valve is controlled from the top of the tower, while the emergency valve is controlled at the bottom of the tower. The spillway was originally rock-lined, but it was reconstructed with a concrete liner in 1945. The spillway is 90 feet wide at the crest and tapers to 50 feet wide at the toe with a maximum capacity of 8,300 cubic feet per second (cfs).

The Willow Creek Water Users Association (herein called "association") operates the dam. Water from the reservoir is used for irrigation water supply. The reservoir also is used for water-based recreation.

Figure 1. Willow Creek Dam Location Map

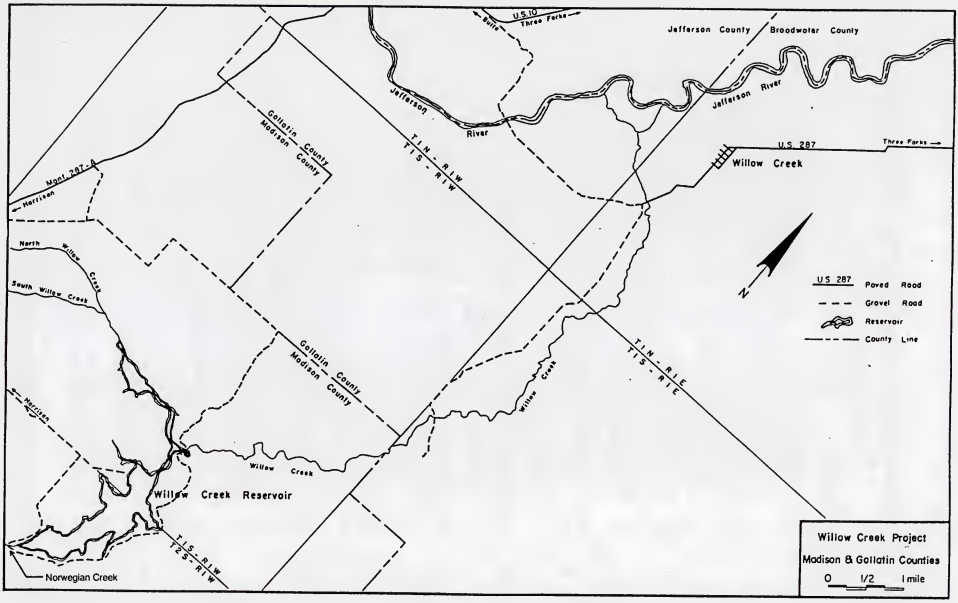

Figure 2. Willow Creek Dam Project Area Map

STATISTICAL INFORMATION

1.	General		
	a)	Owner	Montana Department of Natural Resources and Conservation (DNRC)
	b)	Operator	Willow Creek Water Users Association
	c)	Location	Section 35, Township 1 South, Range 1 West (dam location)
	d)	County--State	Madison--Montana
	e)	Watershed Location	Willow Creek, Jefferson River Basin
	f)	Drainage Area	155 square miles
2.	Principal Elevations (feet above mean sea level)		
	a)	Minimum Dam Crest	4,744.5 feet
	b)	Normal Full Pool	4,736.0 feet
	c)	Toe of Dam	4,639.5 feet
3.	Reservoir		
	a)	Length of Maximum Pool, north and south (approximate)	2.0 miles
	b)	Length of Maximum Pool, east and west (approximate)	1.6 miles
	c)	Maximum Reservoir Level of Record (June 30, 1963)	4,736.7 feet (19,230 acre-feet)
	d)	Surface Area at Normal Pool	885 acres
4.	Storage		
	a)	Maximum Storage (elevation 4,744.5 feet)	26,600 acre-feet
	b)	Active Storage (elevation 4,736.0 feet)	18,000 acre-feet

	c)	Maximum Surcharge	8,600 acre-feet
5.	Hydrology		
	a)	Probable Maximum Flood (PMF)	59,400 cfs (147,000 acre-feet)
	b)	500-Year Return Period Flood	4,618 cfs
	c)	100-Year Return Period Flood	3,090 cfs
	d)	Maximum Inflow of Record (1938-1992) at USGS gage 06035000 (2.2 miles upstream from the dam on Willow Creek)	813 cfs
6.	Embankment (Dam)		
	a)	Type	Earthfill
	b)	Hydraulic Height	105 feet
	c)	Crest Length	453 feet
	d)	Crest Width	28 feet
	e)	Downstream Slope	1v on 1.5h
	f)	Upstream Slope	1v on 3.0h
7.	Outlet Works		
	a)	Size	60-inch, horseshoe-shaped, reinforced concrete and cast iron
	b)	Length	362 feet
	c)	Control	54-inch diameter gate valve upstream (emergency gate) and a 54-inch butterfly valve (operating gate)--gate valve is operated from the bottom of a 96-inch diameter tower, while the butterfly valve is operated from the top of the tower

	d)	Discharge Capacity (at elevation 4,744.5 feet)	700 cfs
	e)	Design Invert Elevation	4,666.5 feet
	f)	Trashrack	Yes
8.	Spillway		
	a)	Location	Left abutment
	b)	Type	Uncontrolled ogee
	c)	Width	90 feet tapering to 50 feet
	d)	Length	240 feet
	e)	Capacity (at elevation 4,744.5 feet)	8,300 cfs

OPERATING PROCEDURES

The association operates Willow Creek Dam and Reservoir to provide an adequate supply of irrigation water to meet contracts with water users without exceeding safe storage or flow levels.

METHOD AND SCHEDULE OF OPERATION

The association's goal is to have the reservoir full before contract holders start putting in calls for water. Except during very dry years, the reservoir fills, and some water flows over the spillway. The date the irrigation releases begin varies from year to year, with late April typically being the earliest. Irrigation releases usually end by October 1. The actual dates that releases begin and end depend one each year's climatological and hydrological conditions.

The maximum reservoir elevation for winter storage is 4,726.0 feet with 10,924 acre-feet of storage. This winter maximum helps prevent damage to the riprap and embankment from wind-driven waves and ice. The minimum reservoir elevation for winter storage is 4,676.0 feet with 498 acre-feet of storage. This winter minimum helps prevent ice damage to the inlet structure for the outlet works.

SAFE DRAWDOWN

Because the stability of Willow Creek Dam has not been thoroughly investigated, DNRC recommends that drawdown rates not exceed one foot per day.

LIMITATIONS OF APPURTENANCES

Appurtenances at Willow Creek are the outlet works and the spillway. The capacity of the outlet works is 700 cfs at the minimum dam crest. In addition, the spillway will discharge 8,300 cfs with the reservoir water elevation at the dam crest. When the spillway is discharging 8,300 cfs, the side walls of the chute may be overtopped. The extent of such overtopping and the resulting damage to the spillway are unknown. The spillway rating table is shown in Appendix A.

DAM OPERATOR

The responsibility for the daily operation of the dam and reservoir rests with the association and its dam operator. The dam operator is generally authorized to operate the reservoir to meet the association's goal. The dam operator's specific responsibilities are to:

1. Operate the mechanical features of the outlet works.
2. Coordinate filling of the reservoir and the release of water.
3. Notify the State Water Projects Bureau (SWPB) of unusual occurrences such as impending floods, excessive seepage, etc.
4. Perform various maintenance tasks.
5. Monitor weather conditions.
6. Monitor seepage.

Typically, the out-going dam operator and the association train a new dam operator. The dam operator's training focuses on operating the mechanical gates, measuring the storage level, measuring the rate of water release, observing the dam and the area for any unusual conditions, and keeping records.

The outlet gates are normally operated manually with a hand crank. During the inspections by the SWPB, the outlet gates are operated by a portable electric pipe-threading tool, fitted with an adapter to fit the gate's operating shaft. The pipe-threading tool is powered by a portable generator that is brought to the site. The outlet works are intended to be used for controlling the release of irrigation water and not for providing emergency relief.

The dam operator is normally available daily to observe the dam and perform operating functions daily during the times of rapid reservoir filling. During the remainder of the filling and irrigation seasons, the operator is at the dam three to five times per week. At other times the operator visits the dam weekly or monthly. Communication among the dam operator, the association, and the SWPB usually takes place by telephone. During emergencies or unusual occurrences, radio communication may be established so that the dam operator can speak directly with county authorities and communicate indirectly with the SWPB (see *Willow Creek Dam Emergency Plan*).

WEATHER MONITORING

The dam operator monitors weather conditions through local weather forecasts and the National Weather Service.

INTERACTION WITH OTHER DAMS

Except for irrigation diversion dams, Toston Dam and Canyon Ferry Dam are the next dams downstream from Willow Creek Dam. The safety of these dams is not affected by the normal operation of Willow Creek Dam. Similarly, the normal operation of Cataract Dam, located upstream of Willow Creek Dam, is not a safety concern to Willow Creek Dam. Therefore, interaction with other dams is not a

concern during normal operations.

If it appears that Willow Creek Dam will breach, or during other emergency operations, the dam operator will initiate the *Willow Creek Dam Emergency Plan* and notify the operators at Toston Dam (**266-3869**) so they can initiate their Emergency Plan.

INSPECTION AND MONITORING

The SWPB will inspect the dam annually. Appendix B includes an example of a SWPB inspection checklist. In addition to annual inspections, a SWPB engineer will inspect the dam and reservoir during and after heavy runoff and severe rainstorms and windstorms, during high storage periods, and after an earthquake. The embankment is not monitored by instrumentation.

STRUCTURAL FEATURES INSPECTION

Structural features include the gatehouse, outlet works, and spillway (Figure 3). The SWPB will inspect these structures annually as part of its inspection program. Items to be checked or noted include, but are not limited to:

1. Outlet Works

    a) Any differential settlement or movement resulting in cracking of the conduit

    b) Erosion of the seals or concrete by cavitation immediately down stream of the gates

    c) Major seepage of water into the conduit

    d) Major deterioration of exposed concrete due to freeze/thaw cycles or sulfate reactions

    e) Operation of both gates through a full cycle

    f) Free, unobstructed operation of the air vent

    g) Corrosion of any metal

    h) Proper lubrication of the pedestals

2. Gatehouse -- Any damage or vandalism

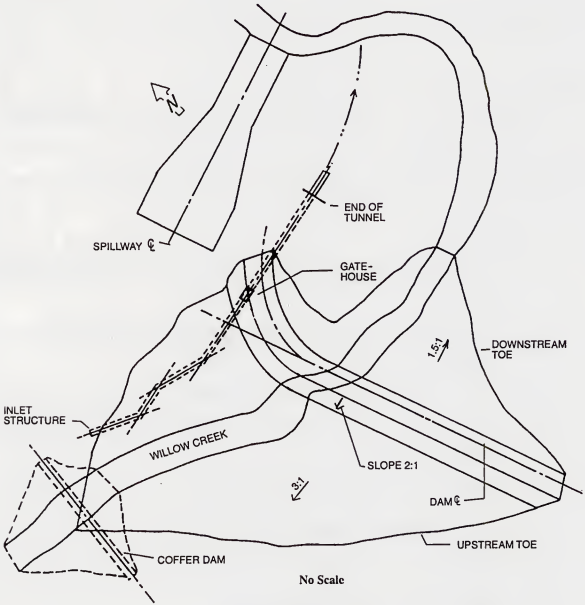

Figure 3. Willow Creek Dam General Layout

3. Spillway

   a) Deterioration of concrete

   b) Separation or movement of joints

   c) Erosion of the spillway chute, backfill behind the walls, or stilling basin

   d) Blockage of the approach or exit channel

RIPRAP INSPECTION

The riprap along the faces of the dam should be at least 30 inches thick. Immediately after the occurrence of high water, SWPB personnel will inspect the riprap and determine if additional riprap is necessary.

SEEPAGE MONITORING

Minor seepage was recently observed at the toe of the right side of the embankment in the backwater pool. It is unclear whether the water is coming from springs or from bank storage in the gravels around the pool. There was no indication that sediment is moving with the water.

A consistently clear flow of up to about 5 gallons per minute seeps from above the outlet tunnel portal.

These areas of seepage will be observed and monitored by the dam operator during regular visits and by the SWPB during annual inspections. To date, seepage measuring equipment has not been installed at the dam. The SWPB is looking into installing seepage measuring equipment, but it has not yet been determined what type of equipment is necessary.

MAINTENANCE

The association is responsible for the project's routine maintenance. During regular visits, the dam operator will identify and perform normal maintenance activities. During the annual inspections, the SWPB will also identify items that need maintenance or repair. The association will be required to perform the maintenance items within the time periods specified. The SWPB may supervise major repairs.

ROUTINE MAINTENANCE

As soon as a need is identified, the dam operator will perform any routine maintenance necessary to protect the dam or keep it in good working order. The dam operator will watch for any potential maintenance requirements during normal visits to the dam. Items that may occasionally need attention include, but are not limited to:

1. Lubrication of gate-operating mechanisms.

2. Debris or silt restricting the spillway inlet or the outlet works. Accumulated debris that could affect the operation of these appurtenances will be removed at once, with all debris removed at least annually.

3. Erosion gullies on embankment. Development of erosion gullies will be checked immediately. Gullies will be filled, compacted, and seeded. Particular attention will be paid to the abutment contact areas and the downstream faces where four-wheel-drive tracks may become a problem.

4. Rodent damage. Rodent burrows will be filled immediately and the rodents removed or destroyed.

5. Upstream slope riprap. Reservoir riprap normally will be maintained annually, but may occasionally need repairs because of high water or wave action.

6. Vegetative cover on downstream slopes. Good vegetative cover will be maintained, but large brush will be removed.

ANNUAL MAINTENANCE

The SWPB will conduct annual inspections of Willow Creek Dam and Reservoir. During these inspections, any items requiring maintenance will be identified and recorded. Items needing annual maintenance include the spillway, outlet works, gates, riprap, roads, and gatehouse. Any other routine items needing immediate attention also will be noted.

After the annual inspection, the SWPB will send the association an inspection report identifying the items that need maintenance. The need to remove trees or brush also will be addressed in the report. The report will ask the association to provide the SWPB with a schedule showing when the maintenance tasks will be performed.

After the association receives the inspection report, it will develop a schedule for performing any identified maintenance tasks. The dam operator or association members may perform these tasks, but major repairs are more likely to be performed by a contractor. The SWPB may assist in contracting for repairs and may supervise the repair work.

RECORD KEEPING

The SWPB will maintain records--including photographs--of all inspections and maintenance requirements. These records will also include flow measurements and storage volumes. Anyone who wants to review these records may do so in the SWPB's office at the Department of Natural Resources and Conservation in Helena.

The dam operator will keep records of the reservoir elevation, seepage observations or measurements, and any unusual conditions. These records may be reviewed at the dam operator's house.

REFERENCES

CH2M Hill. May 1980. *Phase 1 Inspection Report, National Dam Safety Program, Willow Creek Dam, Willow Creek, Montana, Madison County, MT-22.* Prepared for the State of Montana (DNRC) under the U.S. Army Corps of Engineers' National Dam Safety Program.

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APPENDIX A

RATING CURVES AND TABLES

Table A-1

WILLOW CREEK DAM SPILLWAY RATING TABLE

ELEVATION (feet)	FLOW (cfs)
4,736.0	0
4,737.0	350
4,738.0	830
4,739.0	1,550
4,740.0	2,430
4,741.0	3,500
4,742.0	4,700
4,743.0	6,000
4,744.0	7,400
4,744.5	8,300

Figure A-1

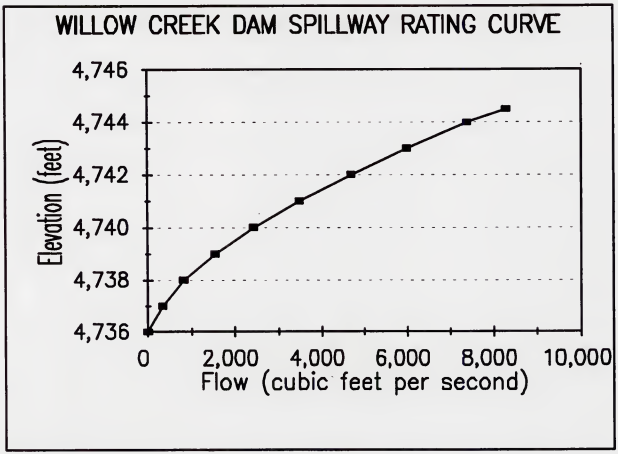

TABLE A-2
WILLOW CREEK DAM
ELEVATION - STORAGE

ELEVATION (feet)	STORAGE (acre-feet)	ELEVATION (feet)	STORAGE (acre-feet)
4,736	18,000	4,700	1,920
4,735	17,203	4,699	1,828
4,734	16,406	4,698	1,736
4,733	15,610	4,697	1,644
4,732	14,813	4,696	1,552
4,731	14,017	4,695	1,460
4,730	13,220	4,694	1,388
4,729	12,646	4,693	1,318
4,728	12,072	4,692	1,248
4,727	11,498	4,691	1,178
4,726	10,924	4,690	1,110
4,725	10,350	4,689	1,056
4,724	9,778	4,688	1,003
4,723	9,206	4,687	951
4,722	8,635	4,686	898
4,721	8,063	4,685	846
4,720	7,491	4,684	803
4,719	7,178	4,683	760
4,718	6,765	4,682	717
4,717	6,351	4,681	674
4,716	5,838	4,680	630
4,715	5,425	4,679	597
4,714	5,039	4,678	564
4,713	4,654	4,677	531
4,712	4,268	4,676	498
4,711	3,883	4,675	465
4,710	3,497	4,674	439
4,709	3,306	4,673	413
4,708	3,114	4,672	387
4,707	2,923	4,671	361
4,706	2,731	4,670	335
4,705	2,540	4,669	316
4,704	2,416	4,668	297
4,703	2,292	4,667	278
4,702	2,168	4,666.5	269
4,701	2,044		

Storage volumes include dead storage of 269 acre-feet.

APPENDIX B

INSPECTION CHECKLIST

DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
DAM SAFETY INSPECTION REPORT

NAME OF DAM _____
DATE INSPECTED _____

INVENTORY NO. _____
HAZARD CATEGORY _____
TYPE OF DAM _____
YEAR BUILT _____

OWNER _____
OPERATOR _____
STREAM _____
DRAINAGE AREA _____

Reservoir Storage Status

	Water Surface Elevation (feet)	Storage (acre-feet)
At time of inspection	_____	_____
At spillway crest	_____	_____
At min. dam crest elevation	_____	_____
Flashboard crest elevation	_____	_____

ITEM	YES	NO	REMARKS	*ICC
1. **EMBANKMENT**				
A. Crest -- Height=	Length=		Width=	
(1) Any visual settlements?				3
(2) Any misalignments?				4
(3) Any cracking?				1
(4) Any traffic damage?				5
(5) Other?				7

NOTE: *ICC stands for "Inventory Comment Code" which is found on the Inventory of Montana Dams. This comment code is for use by the Dam Safety Section.

ITEM	YES	NO	REMARKS	*ICC

1. EMBANKMENT (continued)

B. Upstream Face -- Slope=

(1) Any erosion?				18
(2) Any longitudinal cracks?				9
(3) Any transverse cracks?				9
(4) Is riprap protection adequate?				10
(5) Any stone deterioration?				10
(6) Any visual settlement, slumps, sloughing, depressions or bulges?				9
(7) Adequate grass cover?				14
(8) Debris on the dam face?				15
(9) Other?				16

C. Downstream Face--Slope=

(1) Any erosion?				22
(2) Any longitudinal cracks?				19
(3) Any transverse cracks?				19
(4) Any visual settlement, sloughing, slumps, depressions or bulges?				19
(5) Is the toe drain dry?				31
(6) Are the relief wells flowing?				31
(7) Any boils at the toe?				18
(8) Any seepage areas?				17, 18
(9) Any traffic or animal damage?				22
(10) Any burrowing animals?				21
(11) Adequate grass cover?				24
(12) Other?				25

D. Amount and Type of Vegetation on the Dam

	14, 24

ITEM	YES	NO	REMARKS	*ICC

2. **ABUTMENT CONTACTS**

(A) Any erosion?				12, 20
(B) Any visual differential movement?				12, 20
(C) Any cracks?				12, 20
(D) Any seepage present?				36
(E) Other?				16, 25

3. **OUTLET WORKS**

A. Intake Structure -- Size=

(1) Any settlement?				70
(2) Any tilting?				70
(3) Do concrete surfaces show:				
a. Spalling?				70
b. Cracking?				70
c. Erosion?				70
d. Exposed reinforcement?				70
(4) Do joints show:				
a. Displacement or offset?				70
b. Loss of joint material?				70
c. Leakage?				70
(5) Metal appurtenances:				
a. Any corrosion present?				70
b. Any breakage present?				71
(6) Trash rack?				71
a. Condition?				71
b. Anchor system secure?				71
(7) Other?				71

ITEM	YES	NO	REMARKS	*ICC

3. OUTLET WORKS (continued)

B. Conduit -- Type = Size =

(1) Do concrete surfaces show:				
a. Spalling?				75
b. Cracking?				76
c. Erosion?				75
d. Exposed reinforcement?				76
(2) Do joints show:				
a. Displacement or offset?				75
b. Loss of joint material?				75
c. Leakage?				75
(3) Is the conduit metal?				75
a. Any corrosion present?				75
b. Protective coatings adequate?				76
(4) Is the conduit misaligned?				76
(5) Any calcium deposits?				76
(6) Other?				76

C. Gates and Tower

(1) Gates:				73, 74
a. Size: Operating: Emergency: b. Type: Operating: Emergency:				
(2) Controls operational?				75
(3) Controls lubricated?				75
(4) Operational problems?				75
(5) Leakage around gates?				73, 74
(6) Condition of gate seals?				73, 74
(7) Any cavitation damage? If so, describe?				73, 74
(8) Describe air vent-size and condition.				73, 74

ITEM	YES	NO	REMARKS	*ICC

3. OUTLET WORKS

C. Gates and Tower (continued)

(9) Is there a jet pump?				82
a. Is it operational?				62
b. Leakage?				82
(10) Is the tower dry? ____ wet? ____				77
(11) Any seepage in the tower?				77
(12) Condition of the tower?				77
(13) Any safety problems?				77
(14) Ladder in good condition?				77
(15) Condition of the gate house?				81
(16) Emergency plan completed for the dam?				43
a. Posted in the gatehouse?				43
(17) Other?				82

D. Stilling Basin

(1) Do concrete surfaces show:				
a. Spalling?				62
b. Cracking?				62
c. Erosion?				62
d. Exposed reinforcement?				62
(2) Do joints show:				
a. Displacement or offset?				62
b. Loss of joint material?				62
c. Leakage?				62
(3) Do energy dissipators show:				
a. Signs of deterioration?				62
b. Are they covered with debris?				62
(4) Other?				63

ITEM	YES	NO	REMARKS	*ICC

3. OUTLET WORKS (continued)

E. Downstream Channel

(1) Is the channel:				
a. Eroding or backcutting?				38
b. Sloughing?				38
c. Obstructed?				40
(2) Is released water:				
a. Undercutting the outlet?				52, 62
b. Eroding the embankment?				52, 62
(3) Other?				56,63

4. **SPILLWAY**

A. Description

(1) Location?				N/A
(2) Type of Spillway?				N/A
(3) Size of Spillway?				N/A
(4) Spillway lining?				N/A
(5) Is there a weir?				61
(6) Is the spillway in good condition?				N/A
(7) Any drains?				N/A
a. Describe the condition of drains.				64

B. Does spillway show:

(1) Any cracking concrete?				57, 58
(2) Any spalling concrete?				57, 58
(3) Any exposed reinforcement in the concrete?				57, 58
(4) Any erosion?				52

ITEM	YES	NO	REMARKS	*ICC

4. B. Does spillway show: (continued)

(5) Any slope sloughing?				51
(6) Any obstructions?				54
(7) Displacement or offset joints?				59
(8) Loss of joint material?				57, 58
(9) Leakage at the joints?				57, 58
(10) Other?				63

C. Do the energy dissipators show:

(1) Signs of deterioration?				62
(2) Any cracking?				62
(3) Any spalling?				62
(4) Any exposed reinforcement?				62
(5) Are they covered with debris?				62
(6) Other?				64

D. Has release water:

(1) Eroded the embankment?				52
(2) Undercut the outlet?				52
(3) Eroded the downstream channel?				52
(4) Other?				56

E. Emergency Spillway

(1) Is there an emergency spillway?			(If YES, describe)	55

ITEM	YES	NO	REMARKS	*ICC

5. **RESERVOIR CONTROL**

(A) Recent upstream development?				47
(B) Recent downstream development?				42
(C) Slides in reservoir area?				44
(D) Change in reservoir operation?				42
(E) Large impoundment upstream?				49
(F) Any debris in the reservoir?				50
(G) Other?				50

6. **INSTRUMENTATION**

(A) List type(s) of instrumentation:				27-33
(B) In good condition?				27-33
(C) Read periodically?				27-33
(D) Is data available?				27-33
(E) Include all data gathered since last report.				

7. **DOWNSTREAM CONDITION**

A. Downstream Land Use.

	41

This dam was inspected by:

Additional comments and recommendations. (Use additional pages)